Pre–registration Synopsis
on

Design and Performance Analysis of Solar Scheffler System for Jaggery Making

For the Doctoral Degree in Mechanical Engineering

Submitted
By

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Contents

1. Introduction: 1
2. Literature Review: 4
3. Research Methodology: 8
3.1 Problem Statement: 8
3.2 Methodology: 8
4. Objective: 9
5. Expected Outcomes: 9
Bibliography 10

Figure 1: Solar Scheffler system 2
Table1:Characteristics of solar scheffler system 3
Table 2:Specification of HTF's 5

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1. Introduction:

Solar is the ultimate perceived solution of incessantly proliferating energy crisis. Diverse range of solar energy conversion system has been employed to convert energy into useful form (1). Global warming escalation has extended average temperature of earth beyond it's safe limit. To avert this environmental-threat, solar energy has acquired substantial attention of remarkable researches in this century (2). Quick dwindling of fossil fuel reserves and increase in demand at an alarming rate. Realization of these two aspects led scientists and engineers look for alternatives. many options have been found and examined.

- Prominent among the options are as following.
  - Solar thermal,
  - Solar photovoltaic
  - Wind energy
  - Geothermal Tidal and wave energies.
- Among these, solar energy is relatively more uniformly available. Also according to one estimate, the energy that reaches the Earth from 20 days of sunshine is equal to the energy stored in all of Earth's reserves of fossil fuels like, coal, petroleum, and natural gas.
- Commonly talked about alternate energy sources are, solar energy, wind energy, bio-mass, wave and tidal energy, and geothermal sources etc. Among these, solar energy appears to be the most promising.
- **Solar Scheffler dish system**

  Scheffler dish is a small lateral section of a paraboloid, which concentrates sun's radiation over a fixed focus, with an automatic single axis tracking. Scheffler dish is made of number of flat shaped mirrors or reflective films which are mounted on a

structural frame. The dish rotates about north-south axis parallel to earth's axis to track the sun's movement. The scheffler reflector also performs change in inclination angle while staying directed to sun, in order to obtain sharp focal point. Receiver at a fixed location captures the concentrated heat and transfers it to water/thermic fluid to generate hot water/hot thermic fluid or High-pressure steam.

Fig.1 Solar Scheffler system

- **Key components of Scheffler dish**

  • Reflector dish

  • Receiver

  • Dish stand

  • Tracking System

  • Piping and Insulation

  • Instrumentation and Safety Mechanism

  • Thermal Energy Storage (TES)System

Table 1. Characteristics of solar scheffler system.

Particulars	Specification
Area	16 m2
Heat transfer fluid	Water
Tank capacity	28.5 l
Receiver capacity	18 l
Steam flow rate	5 l/h
Steam output	104 °C
Receiver material	Cast iron
Receiver thickness	5 mm
Thickness of insulation	35 mm
Materials of insulation	Aluminum gladding and glass wool

Traditional jaggery making Process

Jaggery making is one of the largest agro-based industries of unorganized sector in India (6). It is a traditional form of sweetener produced and utilized in rural villages from very long time. In India, jaggery is produced by tradition methods. The major unit operations are

1. Juice extraction
2. Clarification
3. Heating and concentration
4. Cooling
5. Moulding
6. Packaging

The preparation of jaggery is considered as a small scale industry, giving employment to many farmers in rural India.

2.Literature Review:

Classification of literature

- Thermal energy storage (TES) system for CSP.
- Heat transfer fluids (HTF) and Thermal energy storage materials
- Application of nanofluids in solar thermal system.
- Jaggery making technologies

1.Thermal energy storage (TES) system.

- Thermal energy storage (TES) systems correct the mismatch between the supply and demand of energy.

Thermal energy storages

- Sensible heat storage
- Latent heat storage
- Chemical reaction heat storage

- **Liquid sensible heat storage for CSP**

1.Single tank direct storage system

2. Two tank direct storage system

3. Two tank indirect storage system

2. Heat transfer fluids (HTF) and Thermal energy storage materials

- The heat transfer fluids used in CSP technologies include air, water, molten salts, glycol based, glycerol based and synthetic oils which can transfer heat effectively.
- Air and water are not being used now-a-days as air upon heating will increase by volume and so the heat exchanger to be installed should be of larger size for efficient heat transfer which also increases the investment cost to a greater extent.
- Water on high temperatures will get oxidized quickly that can encourage the materials of the absorber tube to react and can cause corrosion in the inner parts of the tube.
- Molten salts have the tendency to get solidified when it reaches high temperature i.e 600 ºC. Glycol based fluids are used for applications below 175ºC and synthetic fluids for applications above 400ºC

Criteria for selection of HTF & Storage materials

From the literature surveys, the criteria for selecting the heat transfer fluids and storage materials are selected those are as follows.

- High operating temperature
- Stability at high temperature
- Low material maintenance and transport costs
- Non-corrosive
- Safe to use
- Low vapour pressure
- Product life cycle
- Low freezing point
- Low viscosity

The heat transfer fluids mainly used in concentrated solar power are based on the selection criteria specified above and few HTFs are listed down with their properties that are collected from different literatures. Out of the heat transfer fluids used in present days, Therminol VP-1,Solar salt and Hitec molten salt are used for experimentation.

Table 2. Specification of HTF's

HTF	**Tmax (K)**	**Cp (KJ/kg.K)**	**ρ (kg/m3)**	**K (W/m.K)**	**μ (mPa.s)**
Xceltherm	580	3	672.3	0.113	0.252
Bipheny	500	2.03	869	0.118	0.32
Phenylnaphthalene	600	2.6	849	0.077	0.11
Therminol VP-1	673	2.73	672.5	0.0771	0.12
Therminol 66	648	-	1011	0.09	0.29
Nitrate Salts	873	1.495	1899	-	3.26
Hitec	720	2.319	1992	-	6.37

3.Application of nanofluid in solar thermal system

Conversion of solar energy into thermal energy requires efficient convective, conductive and radiative heat transfer between the mediums. For thermal energy absorption, commonly

fluids used are water, oil and ethylene glycol but these fluids are not much efficient because of their low thermal conductivity.For obtaining high thermal conductivity, nanofluids are utilized instead of common fluids (4). Nanofluid term was first introduced by choi(5). It is suspension of particles ranging in size of 1-100 nm in base fluids.Nanofluids has better thermo-physical properties than base fluid so to enhance the efficiency of system ,researchers used nanofluids as a working fluid(2).Nanofluid have a massive impact on heat transfer and system overall efficiency compared to base fluid in solar energy systems(2).

Moreover various challenges and critical parameter are

1. stability of nanoparticle in base fluid.
2. flow rate of nanoparticles
3. Size of nanoparticles
4. Type of nanoparticles

4. Jaggery making technologies

From last three decades it is seen that this sector downfall due to many factor(6).Jaggery making annual production has declined from 8.52 to 4.47 MT during last three decades and it's per capita availability has also reduced from 12.5 to 3.7 kg/year during this period(6).The major factor's responsible for jaggery sector downfall have been poor technological interventation for,

1. Juice extraction.
2. Open pan furnace(heating & boiling system)inefficiency.
3. Jaggery moulding and packaging.
4. Quality control and hygiene issues, lack of technical skill.
5. Use of bagasse as a fuel in traditional jaggery making. (that leads to environmental degradation)

So in order to modernize the jaggery making process more sustainable, there is a need of clean (solar) energy for heating and boiling purpose.The inventory of Jaggery making in a regular procedure involves the spatial distribution and the estimated flows for the following major pollutants: nitrogen oxides (NOx), particulate material (PM), carbon dioxide (CO2) and total organic carbon (TOC).As an attempt to reduce the pollution we have to designed a system which will be using superheated steam to heat sugarcane juice. Generation of steam will be done by using solar concentrator.

Research Gap / Conclusion from literature review:

- In jaggery making open pans, designed and fabricated by local artisan are used for boiling and juice concentration. The juice boiling in open pans on simple circular pits made with bricks boundaries support gives very poor fuel heating efficiency.
- From last three decades it is seen that this sector downfall due to many factor.
- So in order to modernize the jaggery making process more sustainable, there is a need of clean (solar) energy for heating and boiling purpose.
- Literature suggest that nanofluid have a massive impact on heat transfer and system overall efficiency compared to base fluid in solar thermal system.

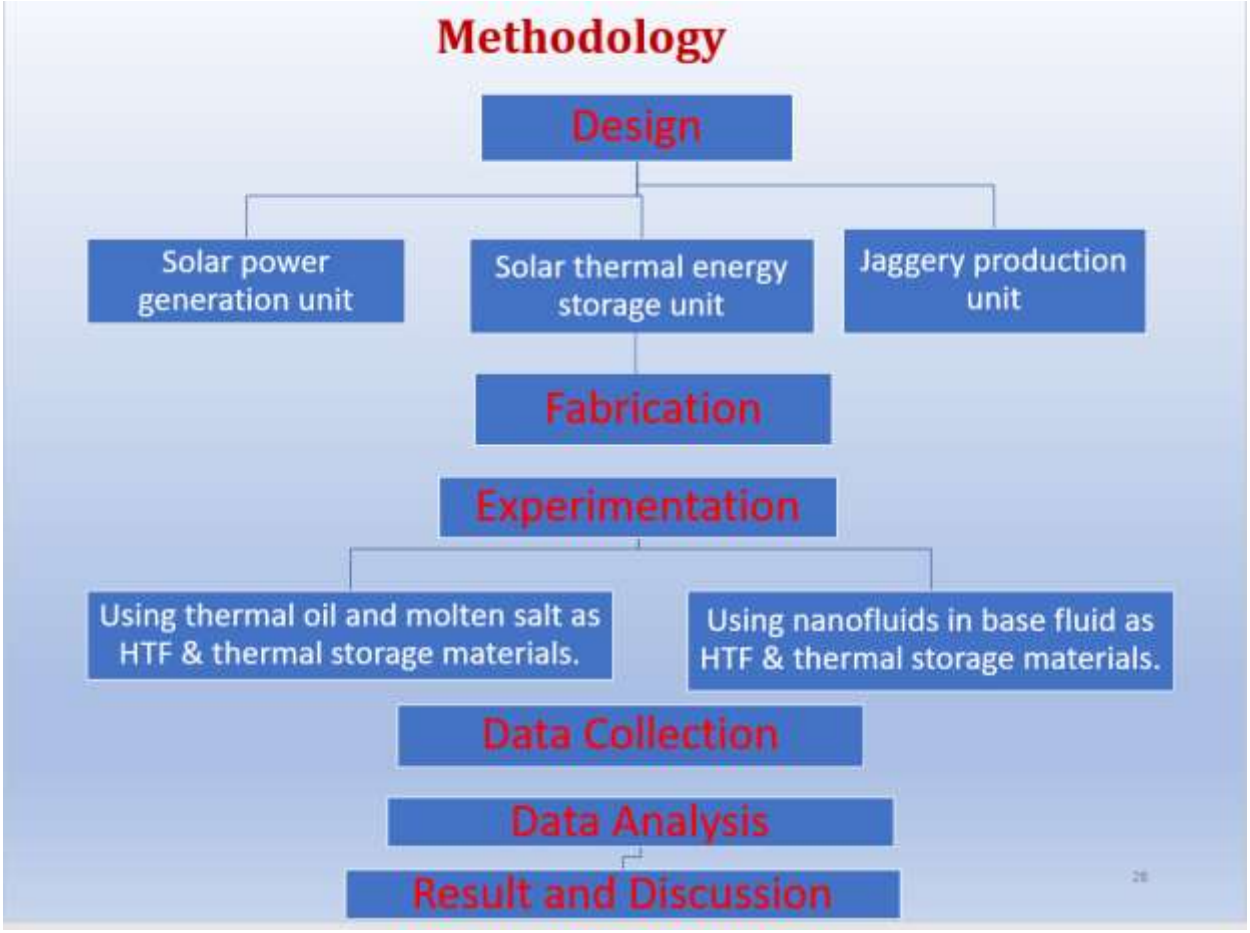
3.Research Methodology:

The proposed work will be carried out by design, experimental investigation and analysis of jaggery plant using solar Scheffler system.

3.1 Problem statement:

Design and Fabrication of Solar Energy Operated Jaggery plant to make jaggery making process more sustainable. Also evaluate the performance of existing solar Scheffler system with thermal energy storage (TES) using oil, molten salt and nanofluids in base fluids as heat transfer fluid (HTF).

3.2 Methodology:



4. Objectives

1. To Design and Fabrication of Solar Energy Operated Jaggery unit to make jaggery making process more sustainable.
2. To Design thermal energy storage (TES)for existing Scheffler system and analyzed its performance.
3. To Analyzed the performance of Solar Energy Operated Jaggery unit with different nanofluid in base fluids as HTF (heat transfer fluid (HTF).
4. To Compared the performance of jaggery unit using base fluid(water) and Nanofluid as HTF.

5.Expected Outcomes:

- This study consist an experimental analysis of jaggery making using solar scheffler system.
- The proposed work will be an attempt to evaluate the performance of existing solar scheffler system to make jaggery making process more sustainable.
- With the proposed work planned to be undertaken, the following outcomes are expected to be achieved.

1. **Reduce carbon footprints.** (As we provide clean (solar) energy for heating and boiling purpose.)
2. **Increase the heating and boiling efficiency of tradition jaggery making process.** (As we use steam.)
3. **Improve Quality control and hygiene issues.**
4. **This environment friendly method will help farmers and society.**

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